

VOLUME VII. }
NUMBER 5. }

[COPYRIGHT, 1890.]

MAY, 1890.

Annual Subscription \$5.00.

Single Copies - 50 cts.

TRANSACTIONS
OF THE
AMERICAN INSTITUTE
OF
ELECTRICAL ENGINEERS.

MONTHLY MEETING, APRIL 2ND, 1890.

SUBJECT:

Phenomena of Alternating Current Induction.

BY PROF. ELIHU THOMSON.

ANNUAL MEETING, MAY 20TH, 1890.

SUBJECT:

Electricity in the Navy.

BY GILBERT WILKES.

NEW YORK CITY:

PUBLISHED BY THE INSTITUTE, UNDER THE SUPERVISION OF
THE EDITING COMMITTEE.

R. W. POPE, *Secretary*,

12 WEST THIRTY-FIRST STREET.

OFFICERS AND MEMBERS OF THE COUNCIL.

1890-91.

PRESIDENT:

PROV. W. A. ANTHONY,
Term expires 1891.

PAST-PRESIDENTS:

DR. NORVIN GREEN, 1884-5-6. T. COMMERFORD MARTIN, 1887-8
FRANKLIN L. POPE, 1888-7. EDWARD WESTON, 1889-9.
PROF. ELIHU THOMSON, 1890-91.

VICE-PRESIDENTS:

EDWARD WESTON,
Term expires 1891.
Dr. SCHUYLER S. WHEELER,
Term expires 1891.
Dr. EDWARD L. NICHOLS,
Term expires 1891.

FRANCIS B. CROCKER,
Term expires 1892.
FRANK J. SPRAGUE,
Term expires 1892.
JOSEPH WETZLER,
Term expires 1892.

MANAGERS:

CHARLES OUTTRISS,
Term expires 1891.
GEORGE B. PRESCOTT, JR.,
Term expires 1891.
THOMAS D. LOCKWOOD,
Term expires 1891.
WILLIAM MAVER, JR.,
Term expires 1891.
Dr. F. BENEDICT HERZOG,
Term expires 1892.
Dr. WM. E. GEYER,
Term expires 1892.

H. C. TOWNSEND,
Term expires 1892.
FRANCIS R. UPTON,
Term expires 1892.
J. C. CHAMBERLAIN,
Term expires 1892.
P. B. DELANY,
Term expires 1892.
HORATIO A. FOSTER,
Term expires 1892.
H. WARD LEONARD,
Term expires 1892.

TREASURER:

GEORGE M. PHELPS,
156 Broadway, New York.

SECRETARY:

RALPH W. POPE,
17 West 51st St., New York.

Term expires 1891.

BOARD OF EXAMINERS:

W. B. VANNEER, Chairman.

F. W. JONES. R. T. BIRDGALL.
O. O. MAILLOUX. EDWARD P. THOMPSON.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The forty-fifth meeting of the Institute was held at Columbia College, New York City, April 2d, President Seth Low, of Columbia College, in the chair, who welcomed the Institute with the following address:—

PROFESSOR THOMSON AND GENTLEMEN OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS: It is a very great pleasure to me, as President of Columbia College, to welcome you to our buildings this evening. You remember that at the Philadelphia Exposition of 1876, over the portals of the Egyptian Department was an inscription something to this effect, "Earth's Oldest Nation to her Youngest, Greeting." And so it seems a very fitting thing that the oldest educational institution, certainly of a high order, in New York City, should give this welcome to representatives of the youngest of the sciences. (Applause.) I can assure you that you could go to no place on this Continent where you would receive a happier or more sympathetic or more intelligent welcome; for there is this difference between old Egypt and old Columbia—whereas the greatness of Egypt lies in her past, those of us who are working in Columbia to day are sanguine with the expectation that what Columbia has been and done in the past is only the earnest of what she will be and do for science, for all education, in the coming time. (Applause.) And that which we think of Columbia we think of you, and that which the electrician has done in the past is only the earnest of what he yet shall do. I rather expect to see the day when this little Electrical School here, which has just been started under the auspices of Columbia, may need a building larger than any one we have upon this block for the proper execution of its work and for the proper care of its collections. And this is to be thought of and remembered by you who come to us from a distance, that whereas some colleges have given their attention to science out of funds specifically donated for that purpose, all that Columbia has done through her School of Mines and its many-sided activity, she has done out of the general purse. She has recognized that valuable as letters are, valuable as the classics and philosophy are, science is equally entitled to her care. As men of science I suppose that is all you will ask. Again I welcome you very cordially, Mr. President and all your colleagues, to Columbia College.

PHENOMENA OF ALTERNATING CURRENT INDUCTION.

BY PROFESSOR ELIHU THOMSON.

MR. PRESIDENT, LADIES AND GENTLEMEN, AND MEMBERS OF THE INSTITUTE: The subject which we have in hand this evening is more of an experimental character than otherwise, and the object is to bring before the Institute chiefly the results of some actions in relation to alternating currents—actions which are novel and curious, and some of which have never before been shown to the public. Others formed the feature of the exhibit which we made at Paris in the past year. The lecture will deal chiefly with effects producible in closed conductors or closed bands subject to the influence of what we call induction. Everyone is familiar with the action produced by passing a current around a bar of iron. If we have a coil surrounding the bar and pass an ordinary continuous current, as it is termed—a current which does not change its direction and does not vary greatly, we get, according to the direction of the current, north and south polarity respectively developed at the ends of the bar and down the sides to some extent, the neutral region or point of no polarity being in a bar of uniform section and of uniform material about the centre. I may say that the magnetization in putting the current through the coil is almost instantaneous, that is to say, if the magnet is of moderate dimensions and we connect it with a battery, we find at once that the ends are north and south in polarity. But if we take such a magnet and surround it with a thick copper tube, or, what will answer just as well, a band of copper, which makes what we call a closed circuit, then we find that on passing the current into the inner coil, for example, the magnetism does not appear instantaneously at the ends, but we have it coming very lazily and

gradually, according to the thickness of this outer envelope of copper. We make what is called a sluggish magnet. We slow up the production of magnetism in the bar. The reason for this is very simple. When we start the current through the inner coil we have at the same moment a reverse or opposing current passing in the outer coil or band which kills or holds back the development of magnetism. After a little while, it may be a second or two in moderate-sized magnets, sometimes even more than that—the magnetism has reached about its normal value as though no band or closed circuit surrounded it. We can in this way construct magnets which will not respond to quick impulses of current, but will only respond to impulses lasting for a certain time. These are facts which are pretty well known and sometimes made use of. But let us now consider what would happen if we were to take away the continuous current and substitute what we call an alternating current—a current which goes in one direction during a portion of the time and reverses, going in the other direction, during another portion of the time. These currents can be made to change their direction many thousand times a second, or we can have them change only a few times a second, or have them change every few seconds. The period or rapidity of vibration or alteration can be varied within the widest limits. We find that with the alternating current passed through the coil—removing the envelope—we will get north and south polarity quickly reversed. That is, every time one current moves one way through the coil, north magnetism will appear at one end of the bar and south magnetism at the other, and when it reverses, the magnetism will reverse, and if the current alternates or changes its direction many times a second, these alternations of magnetism will produce what we call an alternating magnetic field outside of the bar. At the same time we will notice that the alternating current is strongly opposed in its passage by having to reverse the magnetism. That is, it is doing the work of upsetting or turning around the particles of iron in the bar and it encounters an opposition. The poles will reverse rapidly, as I was saying, and we will have magnetism developed, but we will not be able to tell whether it is north or south if the alternating current is changing its course rapidly; but we will find, as I said, that the alternating current will not pass as freely through the coil as a continuous current, but will meet with an opposition which we

call self-induction—or counter-electromotive force. Now, if we put the closed band in place around the coil we will find that the magnetic effects are almost wiped out, and further that the opposition to the passage of the currents through the coil has been almost exterminated. Or, in other words, the coil has now become transparent to the alternations—the alternations passing freely through, whereas before they were very much hindered. Here then, we have another difference from the action which takes place with continuous currents. Furthermore, we find that if this band is loose or movable we will get mechanical actions exerted with the band in certain positions. We make use of these principles in what are called re-active coils for alternating currents, an example of which is found here, (Fig. 1.) If we pass through the coil which you see wound upon this struc-



FIG. 1.

ture, or core made of sheet iron—if we pass a current through this coil, we find that when this copper piece which forms a band around the coil, is over here away from the coil a very great opposition is exerted to the passage of the alternating current, and we can use that coil in order to oppose the passage of such currents just as we would put a resistance in circuit with a continuous current to oppose its passage—with this difference, that wherever we use a resistance in circuit with a continuous current we lose the energy of the current—we waste current; but in the case of the use of such a coil as this—a self-inductive coil—we waste only a small amount of the energy and are enabled to oppose the passage of the alternating current or currents with great force—cut it down without making the loss real.

If now we wish to remove that opposing influence we can do it with the greatest possible smoothness by simply bringing this closed copper band over the coil and we can graduate in that way to the nicest degree possible the force of the alternating current subject to this action. But we would notice, in using the apparatus for the purpose mentioned, that, when we began to bring this copper over the other coil, an opposition to the movement—we would find a repulsion—a tendency to drive back or remove the copper. In fact we can easily imagine that with the copper band in the present position a strong current sent through the terminals of the apparatus would throw it completely over so as to put the full kick or reaction in the

circuit. This repulsive action is one of the phenomena to which I wish to call attention particularly this evening. That is, we propose to make this outer band loose—to give it a chance to move and then study some of the actions obtained. I brought to the notice of the Institute about three years ago a variety of dispositions of parts, apparatus and devices showing this repulsive action, and I explained it, but we had not then the opportunity for actually bringing to the notice of the members the instances of the experimental action of the devices—the devices were not at hand, the current was not at hand, and it was not easy to arrange matters. But we will now make up for that, or try to. Now it is hardly worth while this evening to go into a full discussion of the causes of this repulsion. I will state it very briefly, and it will be a repetition of what has already been said before the Institute. It is simply this—the cause of the repulsion is that in this outer band there will be developed during the passage of the alternating impulses through the inner or inducing coil, currents which are opposite in direction throughout the major part of their time of existence to those which produce them. If we could imagine a current passed through this inner coil producing what may be called the theoretical effect purely, there would be no such repulsion. But there comes into play an action which we call the lag or retardation of the impulse. This action disturbs the opposition of the waves in such a manner as to cause the current produced in the outer band by induction to be opposite in direction to the currents which produce the induction; and opposite currents, according to the laws well known, are repellant; so that if we have two conductors near together, in which opposite currents are flowing, we have a repulsive effort exerted. We ought to get, according to theoretical considerations, and without introducing any consideration of displacement of currents from the theoretical position—a wave which is just a quarter of the wave length back of the wave which induces it. But in actual practice, if we use as the closed band a conductor of considerable size, and of good conducting material, this wave is not so produced; but it is moved, it is shifted to this position, (illustrating); that is, our real wave is not the one the quarter wave displaced, but we find it nearly where I now show it. That is, the current in one coil is in one direction, the current in the other coil is in the opposite direction, and this produces a repulsive

effort. I do not propose to go much further into the consideration of that subject, because we have a number of phenomena to bring before you and that matter has already been discussed before the Institute.¹

One of the earliest experiments which I happened to make as showing somewhat similar action to that just mentioned, was to take a coil of wire provided with an iron core; and support a disc of copper, in a balanced way, in front of it, keeping it properly balanced by counterpoises. We will carefully adjust the weight so as to get it to about a balanced condition. On passing a continuous current through this coil, we simply magnetize the iron inside the coil. We produce suddenly a north pole at this point, but that sudden production of a north pole induces currents in the disc placed opposite to the pole which flow in such directions as to produce a north pole, as it were, pointing downward, so that these two north poles repel each other. If, on the other hand the disc were slightly lifted, and I cut off the current, the disc will at once fall; but if I repeat the operation of putting on the current and taking it off quickly, we find that there is a continued repulsion; or in other words, the disc is kept at a distance from the core. The disc now is down and I will put on the current and you will see it rises about half an inch and is now in oscillation. I tried this experiment about five years ago. You see that every time I put on the current there is a repulsion upward of the disc. If now I quickly make and break the circuit you will see that the disc will stand at a distance. It is thrown

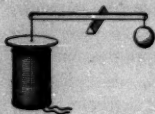


FIG. 2.

off the core. We have, in other words, a repulsion produced by continuous currents quickly interrupted. That is due to the fact that the currents induced or set up by the production of a magnetic pole in this core are attended by the production of other currents in the disc, which oppose the action and drive the disc away. (Fig. 2)

Alternating currents applied to the same conditions may be regarded as very much more rapidly interrupted, and, at the same time, reversed currents, and consequently the magnetic effects are very decided. To show the action with alternating

1. See "Novel Phenomena of Alternating Currents," p. 100, Vol. iv. of Transactions.

currents, we have only to take a plain copper ring and lay it over the coil as you see. (Fig. 3.) We have a source of alternating currents which are conducted from the lines outside, and which are transformed by a transformer to 200 volts, beginning at a thousand volts on the supply lines, and I will close the circuit of the secondary coil, and you see that we have a copper ring resting on a support



FIG. 3.

some distance down the inducing coil. You see this action of repulsion is so considerable as to throw the ring bodily upward. (Applause.) Here the action is exactly what we have before seen, but it is intensified to a wonderful extent. This is a heavy, solid, copper ring, and it is driven, as you see, up into the air quite a height. If I put on the current now for a few moments permanently, I may be able, with care, to balance this ring for an instant in free air. (Applause.) This action of repulsion may be exhibited in very many ways, and, as you see, we have one here, in which instead of holding the ring it is now supported in the air. But that is not all—two rings are as well supported as one.

The reason for this is quite simple. That ring is affected by the alternating current passing in the inducing coil and it is affected in such a way as to produce currents that circulate reversely, but are always behind time as respects the inducing currents so as to be in the opposite direction to these currents at nearly all times. This second ring put under the same conditions is affected in precisely the same way as that ring, and therefore the currents in that ring and in this ring are parallel and in the same direction. Consequently they attract each other instead of repelling. We have then repulsion from this first band and the coil—between this second band and the coil, and because the one is affected like the other, we have attraction between them so that they hang together, and you can hear the tremor of the alternations. That little rattle you hear indicates simply the time when there is no current. The rings fall apart for a moment and before they can get apart another current is set up which

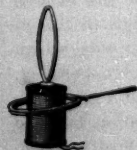


FIG. 3a.

draws them together. (Fig. 3a.)

Not only is this repulsive effect manifested as you see, but if the ring cannot get away from the coil it will undergo what we call the deflective action, or it tends to turn up; besides the ac-

tion is exerted all around the coil as you see. I cannot bring that ring over the coil. It is thrown back. Wherever there is any of this magnetic field the repulsion is exerted and it tends to turn the ring up into the vertical position or plane. The moment I turn it down in this fashion, you see it is with difficulty that I can pass it over the coil. But if we desired to cut off all this effect we would only need to cap that coil with a very heavy copper cap, and then the experiments would take on a very different character. I cannot lay this copper plate on the coil, as you see. This acts just as the ring does. It is a number of rings concentric, all of which can have current developed in them, and it is impossible to lay this plate on the coil, for it is driven away. If I were to cut the current off and lay the ring down, and then put on the current in the inducing coil, the copper disc would jump off. That is the case, too, with a silver coin if we get the field strong enough. There is hardly force enough there; but if we get a very powerful field a silver coin will be thrown completely off. This disc we may say exhausts the magnetic field. If I lay it in the field and force it down I get an effect preventing the passage of magnetic force through it. Here is a lamp which I light simply by connecting it with a coil and bringing the coil near this coil or pole. Notice when I put the copper plate between. Now we will insert the copper plate—the lamp is extinguished. And the moment we withdraw the plate it lights again, and we can graduate its intensity, and as it were turn the lamp up and down as we do with gas. (Fig. 4.) I call this a shading action—that is, the



FIG. 4.

plate shades the magnetic field. Or it may be said to be a deflector—it deflects or reflects the magnetic field. It is like a polished plate of silver as compared with light, and we have only to bring it down to the field and we find that the field is diverted and kept from passing through, so that it cannot affect the coil on the upper side which would feed the lamp if the field were not shaded.

We could vary these experiments to a great extent, and I had prepared a few examples of variation, but one of them met with an accident—that was this little floating lamp. This little lamp ought to be connected with the coil, but it got broken on the way, and therefore I cannot show the experiment. It was to be placed in this glass vessel full of water, and, as you see, it would fall to the bottom. If the circuit had been complete, on putting it into the field, we would not only see the lamp

light under the water by the sheer effect of the magnetic field traversing the water and producing light in the lamp, but we would also see at the same time the lamp rise, and we would have both phenomena—the production of current, demonstrating that the action is due to current developed in the coil because the current lights the lamp, and we would also have the repulsive action of the current. It is a very pretty experiment, and I am sorry it has been prevented by this accident.

There is another point, however, I cannot leave out in connection with it, namely, that we might have the coil floating in the liquid at a certain height as repelled, and then by diminishing



FIG. 5.

the current here in the inducing coil we would find that instead of having the lamp changing its brilliancy it would simply settle down and remain of the same brilliancy as before; that is, the repulsive effort would become less. It would drop to a position where the repulsive effort was as much as before, and then the lamp would have the same brilliancy. We have, as it were, an automatic regulator for the lamp by which, no matter how the current varies,

we can have a standard illumination. (Fig. 5.)

But fortunately I have arranged to show this in a different way. I have a lamp and coil which are placed on the end of a lever. This gets rid of the liquid and gives us a means of balancing the lamp at any brilliancy we desire. I there place the little lamp on the lever, put counterpoising weights on the other side, and you see it floats or is balanced at a distance from the coil. But if the inducing current were slightly diminished, we would find that the lamp would settle down. In fact, it does always rise and fall a little from the variations on the circuit. I may set that lamp then to burn at a certain brilliancy and if I wish

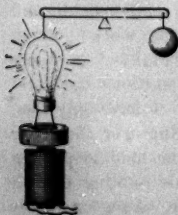


FIG. 6.

to vary the brilliancy I take off a weight from the counterpoise and it rises in brilliancy. If I add more weight to this side I would, of course, diminish the brilliancy, and it might remain balanced under these still new conditions. I take off several of the counterpoise weights. There we have considerable increased brilliancy given, and the lamp will remain so, no matter whether the current fluctuates or not, providing we

always have a space between the coils, which will enable it to go and come and preserve its proper brilliancy. (Fig. 6.)

It will readily be seen from what we have shown that we have a mechanical effort exerted tending to drive away this closed conductor. We could easily use that mechanical effort to produce a movement from alternating currents. We can in fact use it to produce a rotary motor which turns continuously by simply being supplied with an alternating current. We can use it in the measurement of alternating currents. It has been applied to meters, to regulators, to motors, and in various ways. But it is not my purpose to go into the details of its application this evening, as we have much other matter which will take up the time. I would simply say that motors have been made which run with considerable power, and which appear to have a fair efficiency, and at the same time are self-starting—based on the principle of simply closing a circuit when it is in the proper relation to the alternating current coil, allowing it to be repelled to a distance away, then closing another circuit, and so on, making what is called the transformer type of alternating current motor. Now, we have come to another department of the subject growing out of the experiments which I showed with this ring and the other ring. I have shown that if one ring be placed over the coil and another ring be brought under it there is a tendency to attraction. An attraction is exerted which brings the one ring directly over the other ring. Evidently we could use this principle also as a source of motion, because these two parallel currents may be made to attract each other, but the limit of the movement is at once found. When the rings are parallel substantially, they cannot move farther—they cannot get any nearer than when they touch. But we can so modify these effects as to produce a continuous rotation, and I will show a few instances of that. I may take a copper disc mounted on pivots and this copper ring. I place the ring here over the coil and the pivoted disc alongside. Perhaps I can work it at an angle so that the effect may be better seen. (Fig. 7). It occurs



FIG. 7.

with greater vigor in this position; the revolution becomes very rapid. I have only then to put this closed circuit ring over the other or inducing coil; modify the field by placing it there, and then put this rotating disc in front of the magnet there, above or below

the ring—it doesn't matter which—if I put it above I get the effects of rotation, and if I put it below I get the same effects precisely—either one side or the other this ring may go, and the disc is set into rotation. This disc is in essence nothing more than a series of rings which can be thrown into parallelism or attempted parallelism with the first ring or band and then finding new material to one side and which has not got into parallelism, a renewal of the action goes on and results in rotation of the disc. But I wish to call attention to one fact, that if I put the ring exactly concentric with the inducing coil I do not get such effects; I must displace it laterally. No movement occurs if I place it exactly concentric—it is difficult to find that point in this case—and if I err ever so little, the disc begins to revolve. If I carry it over to the other side the disc revolves in the other direction. The effect is very easily obtained also by substituting for the ring a plate of copper. (Fig. 8.) That is, the



FIG. 8.

plate is virtually a ring or a set of rings, as well as the disc, and if I place this sheet of copper in front of the pole the actions are the same as before, and if I wish to reverse the action I place it on the other side. In fact any closed circuit that I may make or bring into position in this field will so modify the field that the disc will be set in motion. It is not necessary at all that we use a copper disc. We may use an iron disc, but then we will notice something quite different. The iron disc is vigorously attracted, and we have to be careful not to let it be pulled down. You see the iron disc is now in rapid rotation in the same way, and is reversed in the same manner as with the copper disc, but there is a real difference between iron and copper in this connection, as we will see. I will put this copper disc here vertically to the ring. Now it has come to rest in a balanced position. It does not rotate, but it does rotate if I put it down in this position, parallel with the field modifying ring. Let us take the iron instead and there is no trouble about the iron in the vertical position. Hence you see we have really a difference after all. The copper and iron do work alike, but they do not work alike altogether. Now the fact is that we have come to deal with two different phenomena in these cases. This copper works when it is parallel with the plate or closed ring because its action depends on the circulation of currents in the plane of the

disc, which cause it to rotate. The iron will work just as well one way as the other way, and at all angles, because it does not depend for its action upon currents that are set up in the iron, but simply on the property which iron has of not changing its magnetism until it is forced to. That is, it has the property sometimes called by the term magnetic friction—magnetic lag, or the more modern term “hysteresis.” It is not exactly like air in its magnetic capacity. It has, in other words, a tendency to remain magnetized as it was, and so resists change when we place it in a field which forces it to change. We place it in front of a pole which does not remain north or south, but which is constantly changing from north and south and at the rate of about 250 times a second of change. Hence, if the lower part of the iron disc gets magnetized north and the top becomes south, instantly, if this disc cannot accept the new condition of reversed poles from the core below with great readiness, it is evident that the polar part of the disc wants to leave, and the new portion, which has not been given a magnetic polarity, will tend to be brought into play instead. But when we place the disc over the inducing coil or core in this manner in a vertical plane, it simply oscillates a little and comes to rest. It does not know which way to turn. It might just as well go out one way as the other, but now this ring or closed circuit decides the question. The copper plate decides that the iron shall move in one certain direction. Now, we may analyze this action a little on the blackboard, because here we shall find a key to all these actions. We will take our magnetic pole which is changing north and south and we will take our sheet of copper partly covering that magnetic pole. Take the disc of copper and place it above. Now, if this pole is north this lower edge of the disc will be south. If this pole is south then this lower edge of the disc will be made north. All above the lower part will become of the other polarity—if south, north up here; if north, south up here. But when we put this copper plate or ring into place, it is inductively acted upon by the pole so as to produce currents in its plane. These currents are not extinguished when the inducing currents are, but are retained for a moment after the former cease and are ready to reverse. Consequently if the current has produced a certain polarity here in the lower edge of the iron disc that current in the plate of copper will attract the magnetism as it were, and pull it towards its own centre.

The polarity if south or north in the disc will be drawn here towards this plate or ring which tends to retain the current which was induced in it. The under side of this ring or plate will be opposite in polarity to that which induces the current, but the upper side will be of the same polarity as the pole of inducing coil just after the impulse of current in the inducing coil is ready to reverse. When we use a copper disc and lay it down horizontally then we have two sets of parallel currents—rings slipping one over the other, and a renewal of the effect continually with every alternation.

I could amplify the disc experiments to a very great extent. Two copper discs may be taken. Now, if my explanation is right it does not really matter which of these is moved. In other words, if currents are set up in this disc which are attracted by parallel currents in the other disc, both should move continuously in a direction to bring these currents together or toward each other. I therefore put this copper disc over the pole on that side, and this other one on this side, and you will see that both of them are set in rotation. (Illustrating.) We are really shading the pole with two discs, and they are revolving in opposite directions. The copper disc may be affected by the iron disc and both revolve. (Fig. 9.) But if I modify the experiment so as to place this copper disc over the pole in this vertical position, and this iron disc in the horizontal position, there is no effect on either disc, but if I take the iron and put it in the vertical position, and the copper horizontal, both of them will revolve after I get the right conditions. My iron disc is not very well balanced. Both discs you see



FIG. 9.

are revolving, but now the iron disc is at right angles to the copper. We could, of course, by properly arranging matters, set a whole mass of discs in operation in different directions, according to the conditions which were chosen. This alternating magnetic field extends away out into the air here, and we could fill it full of discs, provided we did not cut off the field, and they would all be set in motion accordingly.

There are some other curious effects, however, produced in extending this disc experiment. Here is an ordinary steel file. If I take this copper disc and lay the steel file across the magnetic pole in this manner and then hold the copper disc near it, we see that the steel file has the property of setting the disc in

motion. If I take two discs and place them over the steel file at the opposite ends, you will find that they will revolve as though they were geared together—one out this way, and one out the other way. And as above, an iron disc placed in this vertical position over the file will revolve, or we may place it in the horizontal position and it revolves. Here the effect is the magnetic effect—not the current effect, and with the two iron discs the rotation of both of them is produced as you see, whether they lie in that plane or in any plane in respect to the file. (Fig. 10.)

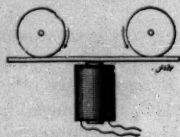


FIG. 10.

It is not even necessary to get this rotary action that we should use the file. We can take the copper disc, place it over the pole flatwise, and then simply bring another core of soft iron over the pole, but displace it a little from the axis of the other core.

And you see we get vigorous rotation. In fact, this is a principle I have used in making, with some success, a small alternating motor. By simply displacing the poles and putting a copper circuit between, the rotation may be made continuous and by multiplying the number of poles a considerable exertion may be obtained.

Cast iron behaves like steel in this connection. Here we have a curious instance of a cast-iron ring on which I have simply wound a little closed coil. I place this ring over the alternating pole say in this manner, symmetrically. I get no tendency to rotation in this iron disc. I have placed the closed coil at the opposite diameter from the inducing pole. If I make the placing unsymmetrical, however, so that the coil is on one side, then you see I get rotation in the concentric iron disc but not very brisk. I simply put the iron disc in position and find that the magnetism in traveling around this ring turns the disc, while this portion of the ring which is covered with a little closed coil, prevents the magnetism from creeping around the ring in such direction, that we do not get the opposing or balancing effect which would stop the disc. The closure of circuit of this coil simply prevents the

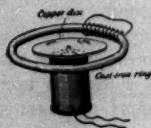


FIG. 11.

propagation, as it were, of the waves of magnetism from the alternating pole in this direction at the same rate that they go in the other direction around the cast iron ring. Consequently we have a rotation of the disc in this direction, and showing us in a different way what we were getting with the file. (Fig.

11.) We were getting waves of magnetism which passed out along the file in each direction, and which took some time to so pass, that is, beginning in the middle of the file at the pole, and moving out and only reaching the end after a little interval; the reason being that the file, although it is not surrounded by closed circuits, as is the case with the cast-iron ring, has another property which I mentioned before—magnetic friction which opposes quick changes of the magnetism. It uses up force to effect such a change. It warms, not by induced current, but by the effort of the field to turn the molecules first one way and then the other in producing opposite polarities. The actual result of that action is as follows: We will consider the instance of the file. That we will suppose is laid across the pole. When the pole is south, the file would be north at its centre. When the pole changes to north the north in the file splits, as it were, and moves outward, while the centre becomes south, and the two norths travel out along the file oppositely, and being north poles they, of course, are surrounded by magnetic lines, and in fact are moving consequent poles for the time being.

Now we may put here a disc of copper or iron, and these magnetic poles or lines are sweeping along the file. They act like magnetic brushes that are brushing the disc around and they disappear in closing themselves up or neutralizing, as it were, at the ends. That is, when a pole in traveling goes so close to the end of the file it is so near an opposite pole as to neutralize it, at which moment the action ceases so far as those lines are concerned, and a new set are sent out to travel along, and this goes on continuously at every wave of alternating current.

We have an example here of a little alternating motor of a very small type which is built up on the principles we have been showing, only we have a different form of magnet. In this case I have a circular core. That is, I have a ring of iron which would return on itself; but I have cut a slot through it of about a quarter of an inch in width. On the sides of the slot I have placed copper circuits which are closed—closed bands in which currents can be produced. But I have off-set them so that there are more on one side than on the other—so that the poles are shaded on one side and not on the

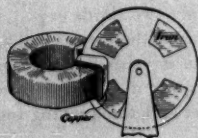


FIG. 12.

other. If I introduce a copper disc into the slot here and put on the current, we will see that we have an alternating motor produced (see Fig. 12), and it exerts some power. This machine, however, I use for another purpose. I have two coins, and one of them I lay on my hand in this fashion just below the slot, and it is drawn in and thrown violently out, upward through the slot. (Fig. 13.) In other words, the silver coin tends to do

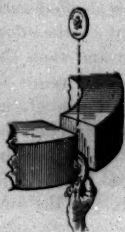


FIG. 13.

what this disc did—continually move up through the slot. But this disc may be regarded as a lot of coins stuck together, and consequently we have continuous movement. Here we have only one disc. But we will try the other coin. With that we get no such effect. It is a counterfeit. (Laughter and applause.) But listen, (ringing the coins), there is not very much difference in the ring. One might easily be deceived. But the machine knows the difference. The silver of the genuine coin is a good conductor. Silver,

even with an alloy of a baser metal, like copper, retains a large portion of its original conductivity. Consequently the currents induced in the silver are much more considerable than can be induced in this base coin, which is not so good a conductor. Anything that imitates silver does not come anywhere near it in conductivity, especially if it is expected to weigh as much as silver, in which case lead is generally one of the constituents; and this alloyed with other metals is still worse. I keep these coins in separate pockets, as you see. (Laughter.)

Now, there are some other curious effects of rotation which are rather modifications of what has already been shown, but they are certainly curious. They are explained on the same grounds which explain the rotations of the disc and to which I have referred. But from their uniqueness they are perhaps more interesting in some ways. They are certainly in a popular sense more interesting, because the actions are somewhat unexpected. Here is a hollow copper ball. I place a brass plate over the alternating pole, and it projects not two thirds over. I place the copper ball on the plate and you see the copper ball at once spins. Placing it on the other side it spins in the other direction. It is behaving just like a copper disc placed over another disc. Here is a little one, a smaller ball, the spinning top of the future.

You have heard the old rhyme about the dish running away with the spoon. I am going to have it modified in this way. I have a brass dish here which will run away with a cup. We have the same spinning-top effect. It is not at all necessary that we use a plate for that purpose. I showed you sometime since the equivalency of a plate with a ring, and I shall now merely make a momentary substitution of this copper ring with a mica sheet, to rest the bodies on, and you will find that the copper ball spins in that ring as though placed on the plate. But a more surprising effect is yet to come. I shall have to put on a guard rail to the apparatus in this case to prevent the ball running away from us. I have two glass pins inserted in a plate which partly shades the pole, and I lay the copper ball against those pins. The ball rotates over this way and actually overcomes the friction of its lower side on the plate. It has to turn on a horizontal axis and its equator rubs



FIG. 14.

the shielding plate. The action is very vigorous, as you see. (Fig. 14.)

One of the interesting modifications of this experiment we will attempt to show. It is somewhat analogous to the experiment of the lamp immersed in water. I put over the core a vase of water. We have the alternating current on. But you see there is no action of the ball. It requires that we place underneath a shading disc. Now, we have a rotation of the ball in the water. This may become quite vigorous, and we obtain extra vigor by putting a copper ring in the water. This is a pretty modification of the other experiments, and has this advantage,



FIG. 15.

that the ball keeps cool. In the other case the ball gets warm. The currents are so energetic that they actually warm the ball. Now the ball is rotating right in the copper dish, and sometimes when we get sufficiently vigorous action the dish and the ball both are set into vigorous rotation. Now, the dish is going about or turning. We might fill the water with small balls. I have had three of them in operation at one time rotating in different ways. (Fig. 15.)

One or two more experiments in this direction. I here have mounted a somewhat different arrangement. I have a little

wheel or rim of copper with an iron interior. That is, it is like the armature of a dynamo wound with wire or covered with a conducting envelope. We place a wedge of iron on the pole and then I shall bring this on the one side or the other of the edge of the wedge. You probably cannot see the action, but you will perhaps take my word for it, that the little wheel is revolving very rapidly, and if I put it on the other side it revolves in the other direction as though a jet of something were shooting off that edge. This jet is nothing more than the traveling system of magnetic lines. You are all familiar with the gyroscope—the instrument which you had generally to spin by winding a cord and pulling it off the shaft. Here is a gyroscope which is the gyroscope of the future. You do not require a string or battery, except the alternating current field. You do not require any connection with the instrument. I put a centre for it to move on in the magnetic pole. Already the little disc is rapidly revolving, and I will let go of it in the ordinary way of the gyroscope, and you will see it turns about. It will get up to quite a speed in a little while and then you will see that the gyroscopic action is very beautifully manifested. Now the thing that causes rotation in this case is the little inclined frame holding the wheel. It does not lie, as in an ordinary gyroscope, horizontally, but it lies in an inclined position. The wheel is simply a copper wheel with a laminated iron core supporting the copper ring. It is getting up a very high speed now, and the gyratory rotation is consequently slow—one of the phenomena of the gyroscope. (Fig. 16 and 17.) To reverse the rotation I would do as with any



FIG. 16.



FIG. 17.

gyroscope—simply move the weight so as to bring the balance outward instead of inward, and then the rotation would be opposite in direction. Now the rotation is in the opposite way. I have over set the gyroscope by putting the weight out from the pivot so as to overbalance it.

DR. GEYER:—Have you ever taken the weight off altogether?

PROF. THOMSON:—I haven't tried that, but it is possible, I

think, with very high speeds. But if I take the weight off the copper frame it does not retain its angular position. I need the weight to hold it in place. I must have the angle of the frame preserved. The deflective action comes into play to turn this circuit to right angles. With this experimental illustration we see that a curious series of phenomena are manifested by alternating magnetic fields.

There is but one other statement I wish to make before closing, and that is as to the marvellous capacity for the transfer of energy which an induction coil possesses. If we could imagine an induction coil, that is, a coil composed of a winding, which acts to produce currents in another winding, carried to a very low temperature, we could have the resistance of the copper to the passage of the current almost obliterated. Then we would find that we could load the copper coils with an enormous amount of current. They could probably be made of tubes and refrigerating fluids passed through them. We would find the actual amount of energy which could be conveyed from one circuit to another by a moderate sized coil and with a core of very moderate dimensions, that is, with an iron core and a magnetic circuit of very moderate dimensions, would be counted by thousands of horse-power. Our experience has taught us that even under ordinary conditions it is no unusual thing to transfer thirty or forty horse-power through a magnetic core which a man can easily lift, and do it efficiently and well. The iron part of the apparatus has very little to do with the action. We could take it out altogether if we could refrigerate our coils and wind the two coils close together. The induction coil is probably one of the most striking examples or proofs, we may say, of the fact that the actual mode of transference of energy along an electric wire is not through the copper of the wire; it is through the medium outside of the wire. The modern view of electricians, gradually becoming more and more credited, is that the wire is merely the core of a set of disturbances which are really propagated around it. That is (illustrating), if we have a wire conductor carrying a varying current, that current is merely an incident of something which is going on all around in the space surrounding the wire, in the ether—in the medium which surrounds all bodies, and which fills all space. Now, it is manifest, if this be true, if the varying current is merely an incident of this propagation of energy in that medium—put another wire

there and you ought to have a current as an incident of the propagation, and if you coil those wires up together so as to make a coil in which two conductors lie side by side as in an induction coil, if the propagation of energy is thousands of horse-power and this current in the centre an incident of that propagation, thousands of horse-power may be represented by the currents of which this is an incident, too; or in other words, the two circuits are in the same relation exactly to that thing which represents or carries energy. The primary circuit and the secondary circuit are really immersed in the thing which is conveying electrical energy, the wire merely serving as a centre around which the energy shall be propagated. I thank you for your attention this evening, and if I haven't been very scientific, I hope I have shown some things which have been of some little interest. (Adjourned.)

ANNUAL MEETING.

At the annual meeting of the American Institute of Electrical Engineers, held in New York City, May 20th, the following Officers and Members of Council were elected to fill vacancies occurring under the Rules.

PRESIDENT,
W. A. ANTHONY,
Term expires 1891.

VICE-PRESIDENTS,
Terms expire 1892.
FRANCIS B. CROCKER,
FRANK J. SPRAGUE,
JOSEPH WETZLER.

MANAGERS,
Terms expire 1898.
J. C. CHAMBERLAIN,
P. B. DELANY,
HORATIO A. FOSTER,
H. WARD LEONARD.

TREASURER,
GEORGE M. PHELPS,
150 Broadway,
New York.

SECRETARY,
RALPH W. POPE,
12 West 31st Street,
New York.

The annual report of Council stated that twelve Council meetings had been held during the year, and ten meetings of the Institute for the reading and discussion of papers. One hundred and three associate members were elected who had qualified, ten have resigned, and seven have died. The total membership of all grades at the date of the report was 427. The net receipts of the year from entrance fees and dues was \$4,372.14, and the net expenses \$4,308.16, showing a net surplus of \$63.98. The balance in the hands of the Treasurer was \$249.26 to the credit of the General Fund, and \$350.00 to the Building Fund. By an arrangement with the American Society of Mechanical Engineers, the future headquarters of the Institute will be at the House of that Society, No. 12 West 31st Street, New York, where meetings

will be held hereafter, and to which all communications should be addressed.

At the meeting of Council held June 17th, Dr. Schuyler S. Wheeler was elected Vice-President to fill the vacancy caused by the death of Major O. E. Michaelis; and Francis R. Upton, Manager, in the place of Henry Van Hoevenbergh, resigned.

JUNE 25th, 1890.

American Institute of Electrical Engineers.

ELECTED TO ASSOCIATE MEMBERSHIP.

At the Council Meeting, May 20th, 1890.

Name.	Address.	Endorsed by
BUNCE, THEODORE D., JR.	Battery Expert, The Julien Electric Traction Co., 239 East 27th St., New York City.	Wm. Bracken. J. C. Chamberlain. R. W. Pope.
BROOKS, MORGAN.	Secretary and Treasurer, St. Paul Gas Light Co., St. Paul, Minn.	W. B. Vansize. G. W. Blodgett. E. T. Gilliland.
PECK, EDWARD F.	General Sup't, Citizens Electric Illuminating Co., Cor. Navy St. and DeKalb Ave., Brooklyn, N. Y.	G. M. Phelps. T. C. Martin. Jos. Wetzler.
JONES, F. R.	Sup't of Construction, The Western Engineering Co., Kearney, Neb.	Edward L. Nichols. D. C. Jackson. H. J. Ryan.
BRADLEY, FRED. W.	United Edison Mfg. Co., 27 Front Street, Schenectady, N. Y.	W. S. Andrews. W. G. Whitmore. J. C. Bennett.
BELL, DR. LOUIS.	Editor <i>Electrical World</i> , 167 Times Building, New York.	W. J. Johnston. W. A. Rosenbaum. Clarence E. Stump.
WILLIAMS, ARTHUR S.	Electrician, American Telephone and Telegraph Co., 18 Cort- landt St., New York City.	F. A. Pickernell. Holbrook Cushman. G. A. Hamilton.
STOREY, IMLE E.	Electrician and Manager, Storey Electric Drill and Power Co., 16 Broad St., New York City.	W. A. Rosenbaum. H. W. Blake. R. W. Pope.
WATTS, H. FRANKLIN.	Electrical Engineer, 1209 11th Street, Altoona, Pa.	W. A. Rosenbaum. C. E. Stump. R. W. Pope.
LOZIER, ROBERT T. E.	Electrical Expert, The Edison United Mfg. Co., 65 Fifth Ave., New York.	W. S. Andrews. Gilbert Wilkes. Chas. Wirt.
SWEET, HENRY N.	Chief of Patent Bureau, Thomson Electric Welding Co., 39 State St., Boston, Mass.	Elihu Thomson. A. L. Rohrer. John C. Lee.
MARKS, LOUIS B.	Graduate Student, Cornell University, Ithaca, N. Y.	Edwd. L. Nichols. H. J. Ryan. R. W. Pope.

Total 12.

ELECTED TO ASSOCIATE MEMBERSHIP.

At the Council Meeting, June 17th, 1890.

Name.	Address.	Endorsed by
DUNDERDALE, CLEVELAND F.	Agent Westinghouse Electric Co., 146 Adams St., Chicago, Ill.	C. O. Mailloux. H. Ward Leonard. Chas. W. Raymond.
HOLCOMB, EUGENE R.	Electrician, Agency Thomson-Houston Electric Co., 234 Montgomery St., San Francisco, Cal.	A. L. Rohrer. G. F. Curtiss. H. Lemp.
SINCLAIR, H. A.	Electrical Engineer. The Tucker Electric Co., 950 Bedford Ave. Brooklyn, N. Y.	C. O. Mailloux. Jos. Wetzler. T. C. Martin.
CHAMBERLAIN, F. H.	Electrician. Metropolitan R. R. Co. 2411 P. St., N. W. Washington, D. C.	C. O. Mailloux. Jos. Wetzler. T. C. Martin.
CUTTER, GEORGE	Dealer in Electrical Supplies, 192 Fifth Avenue, Chicago, Ill.	E. Wilbur Rice, Jr. Elihu Thomson. Merle J. Wightman.
COBB, JOHN S.	with S. R. Krom, General Manager and Mining Engineer, 151 Cedar St., New York.	Jos. Wetzler. Geo. M. Phelps. T. C. Martin.
FISKE, J. P. B.	Electrical Engineer, Thomson Houston Electric Co. Lynn, Mass.	G. F. Curtiss. A. L. Rohrer. W. H. Blood, Jr.
REIST, H. G.	Electrical Engineer. Thomson-Houston Electric Co. 113 Franklin St. Lynn, Mass.	A. L. Rohrer. W. H. Blood, Jr. G. F. Curtiss.
CAHOON, JAS. B.	Electrical Engineer. Thomson-Houston Electric Co. 257 Washington St. Lynn, Mass.	E. W. Rice, Jr. A. L. Rohrer. G. F. Curtiss.
EKSTROM, AXEL.	Electrician. Thomson-Houston Electric Co. Lynn, Mass.	G. F. Curtiss. E. W. Rice, Jr. A. L. Rohrer.
OWENS, R. B.	Superintendent, Greenwich Gas and Electric Light Co. Greenwich, Conn.	T. C. Martin. Louis Duncan. E. F. Peck.
COLGATE, GEO. L.	Electrical Engineer. Bedford Electric Co. Bedford City, Va.	Cecil P. Poole. T. C. Martin. Jos. Wetzler.
MYERS, GEO. FRANCIS	Laboratory of Wm. Stanley, Jr. U. S. Electric Light Co. Newark N. J.	William Stanley, Jr. S. S. Wheeler. Ralph W. Pope.
MASON, AUGUSTÉ F.	General Manager, Simplex Electric Co., 620 Atlantic Avenue Boston, Mass.	Jos. Wetzler. T. C. Martin. C. J. Field.
LUFKIN, HARVEY L.	General Agent, "C & C" Electric Motor Co., 404 Greenwich St. New York.	R. N. Bayles. Jos. Wetzler. T. C. Martin.
POWELL, WILLIAM H.	New Britain, Conn.	Wm. A. Anthony. Edwd L. Nichols. Harris J. Ryan.
FRANCISCO, M. J.	President and General Manager, Rutland Electric Light Co., Rutland, Vt.	Jos. Wetzler. T. C. Martin. C. J. Field.

Total 17,

TRANSFERRED FROM ASSOCIATE TO FULL MEMBERSHIP
BY COUNCIL, JUNE 17th, 1890.

(Approved by Board of Examiners, June 10th, 1890.)

		Elected Associate Member.
LAWSON, A. J.,	Electrical Engineer and Contractor, Montreal, P. Q.	Mar. 18, 1890.
DAVIS, CHARLES H.,	Consulting Electrical Engineer, 120 Broadway, New York.	May 18, 1890.
BROOKS, MORGAN,	Sec'y and Treas. St. Paul Gas Light Co., St. Paul, Minn.	May 20, 1890.
JACKSON, DUGALD C.,	Asst. Engineer, Railway Dept., Sprague Electric Railway and Motor Co., New York.	May 3, 1887.
JACKSON, FRANCIS E.,	Edison Lamp Co., Harrison, N. J.	Jan. 3, 1888.
BELL, DR. LOUIS,	Editor <i>Electrical World</i> , New York.	May 20, 1890.
STEBBINS, THEODORE,	Thomson-Houston Electric Co., (Railway Dept.) Boston, Mass.	July 9, 1889.

ELECTRICITY IN THE NAVY.

BY GILBERT WILKES.

I have taken as my title "Electricity in the Navy" and shall give in my paper the general conclusions derived from five years' more or less intimate connection with the application of electricity in our naval service.

The electrical engineer has little to do with the placing of the dynamo room, which is of necessity governed by the arrangement of the ship as a fighting machine. I shall, therefore, merely consider the power and apparatus of the plant, commencing with the engines.

Both in this country and abroad, compound condensing engines have been used, some having separate condensers, some exhausting into the main condensers of the ship, but the preference seems to be in favor of simple double acting, high-speed engines, the reason being that the power used for electrical purposes is so small in proportion to that of the main engines of the ship (only about an average of one per cent.) that the saving does not pay for the additional complication and cost. However, with a given plant, the engine should be constructed to allow little variation of speed under large changes of steam pressure, in order to take advantage of the main condenser when possible.

In our service both horizontal and vertical engines are now in use, the preference in some cases being the result of the shape of the available space. No data has yet been obtained as to the most economical type, but both are doing good service, the mishaps having been due to accidents. Of late years all of the engines put in for electric lighting have been high-speed, the largest of about twenty-five horse-power and running at 400 revolutions.

The important points in the consideration of a marine dynamo are:—

FIRST:—It should be direct driven. The reasons are obvious, as, not only is the space taken up by the belting valuable, but in a sea way the danger of running belts must be considered, especially when it is taken into account that naval vessels are fighting machines and the possibility of accidents must be reduced to a minimum.

SECOND:—It should be compact. This is a natural extension of the above. Even now it is difficult to find room for all of the machinery, stores and ammunition, besides providing room for berthing the crew on a modern man-of-war.

THIRD:—It should be free from liability to injury by salt water, and not too subject to mechanical damage.

In this respect there remains room for considerable improvement, the latest dynamos now better filling this requirement than did the old "L" machine on the Trenton in 1883, the first dynamo afloat in our navy and which ended its useful career in the great storm at Samoa last year, when it ran until the water had put out the fires under the boilers.

On board ship, salt water and damp air get everywhere and within the last year a number of cases of slight burn out have occurred in armatures, which, when installed, measured high in the hundreds of thousands of ohms insulation. The dynamo should not be easily harmed. The dynamo room is now always low down in the ship, under the protective deck (if there is one), and when the light is not in use, the room is very dark, rendering careful inspection difficult.

FOURTH:—The dynamo should have small effect upon the compasses. This point has received little attention though it is a matter of great importance, as the effect on many vessels is so large that, in order to work up the day's run, it is necessary to know the hours during which the dynamos have been in operation. Complete deviation tables are therefore necessary for the two cases. In different types of dynamos the effect with a twenty horse-power machine, at a distance of 12 feet, will vary from less than one-twentieth of the horizontal component of the earth's magnetism, to several times the strength of the horizontal component. The latter is, unfortunately, rather the rule than the exception, and, in consequence, the position of the dynamo

room has to be well borne in mind in locating the standard compass.

FIFTH :—It should be easy in running and require but little attention. The machine should be non-sparking, under constant load and also be able to stand sudden large changes of load with little sparking. This is necessitated by the fact that the dynamos now supplied for incandescent lighting are also used for search light work and the conditions are aggravated by most of the search lights having hand regulation only. Thus, with a 200 ampere machine, not only are from 50 to 100 amperes thrown suddenly on and off, but at the moment that the operator at the projector brings the carbons together, the dynamo is suddenly called upon to deliver over three-fourths of its total capacity.

SIXTH :—It should be efficient and run cool, the former in order to avoid the waste of energy and a corresponding amount of the coal supply and also in order to avoid over-heating. The dynamo rooms on shipboard are, at best, warm, notwithstanding the motor fans, which are now usually supplied and thus the safe limit of extra heating is reduced. At the same time consideration for the attendants requires that the cramped space be kept as cool as possible.

SEVENTH :—The dynamo should maintain a constant potential at all loads. This is of course accomplished by compounding, and, as there is only about three per cent. drop, it is usual to compound exactly, or to only over-compound enough to allow for the decrease in the engine's speed with load.

EIGHTH :—The dynamo should be light. The reasons are obvious, but it is considered last, because usually a careful study of the materials, and arrangement of the plant, can accomplish more towards reducing the total weight than the strict adherence to a specification of watts per pound of dynamo. Thus, consider the difference between the weights of a 40 horse-power ship plant on a five watts per pound specification, and upon a four watts specification. Two 200-ampere, 80-volt dynamos, with their share of the bed-plates, will only weigh about 7,500 pounds. Twenty per cent. of this will be about 1,500 pounds, an amount, a large portion of which can really be saved in some cases by more careful attention to the amount of wire and moulding employed.

Naturally no one dynamo can best fill all of these conditions, and while the order in which they are above arranged will usually

approximate to their relative importance, special cases arise which demand a re-arrangement. Thus, on torpedo boats, the most important quality is small size. With this in view, numerous devices have been placed upon the market and faithfully tried, but none have to my knowledge proved satisfactory. The requirements of high efficiency, low speed and low heating, all give way in this class of dynamo to the necessity of compactness and light weight. Good results were hoped for from the Parsons turbo-electric generator, but experience at Newport demonstrated that the turbine was so inefficient in its consumption of steam as to place its use out of the question. There is as yet no apparatus to satisfactorily fill this want.

Up to the present all of our ship plants contain one set, or two or more similar sets, each composed of an engine and one direct driven dynamo. The largest of these are of 200 amperes capacity; a very convenient unit, but one which can be doubled in capacity with advantage in ships which are not light below decks and which are likely to soon have extensive motor applications: for example, vessels of the monitor type.

The voltage in use in the navy is eighty volts, this having been fixed upon as a mean between the most efficient pressure for the incandescent system and the voltage necessary for the search lights, to which current is supplied by the regular service machines. The incandescent lamps have given excellent results as to life from the very start, owing in great measure to the fact that low efficiency lamps are always used, nothing more economical than four watts per candle power being usually required.

Search lights of fifty volts and from fifty amperes up are used, two or more being supplied, according to the size of the ship. Some of these are imported, others are made in this country.

The two wire system has always been used in the naval service, the ship never being allowed to form the return circuit. On account of the present beginning of motor work on board ship and the future developments confidently looked for, the direct current has always been used. Motors have thus far been used only in driving small fans up to one half horse power, for hoists, and in one case, a motor has been used for training one of the large guns—on the "Chicago." There are numerous small engines about a man-of-war varying from one to fifty horse power. Some of the smaller ones might even now be replaced with advantage by electric motors, but it must be proved in each case, that the

motor not only does the duty as well as the engine it replaces, but also that it and any increase necessary in the generating plant, take up less room and weigh less than the engine and its piping. This, of course, will always be the case where very small engines are replaced, and, as the tendency is to increase the capacity of the dynamo plant, it may not be long before motors may look for a larger field on board ship.

All circuits are water-tight from dynamo to point of distribution, the cut-outs having stuffing boxes through which the lead covered wires enter. Even the switches and attachment plugs for portables are required, in certain places, to be watertight.

One electrical application that presents many advantages on board a man-of-war, especially when on a foreign station, is electrical welding. However, when it is introduced on shipboard, the pressure of the generator should be reduced to eighty volts, in order that in case of emergency it might be used for lighting purposes, while the welders should have several sets of adjustable clamps. Welding machines have not yet been actually used on shipboard, but it is to be hoped that their introduction is a development of the near future. They can not supplant any of the existing dynamos, owing to the necessity of motors, but must come in to occupy a place of their own, to almost entirely supplant the ship's forge and add to the general useful equipment.

Thus the man-of-war is the proper field for nearly every form of application of electricity and when the storage battery becomes more suited to the service there required, there is no doubt that it too will come in for its proper share of usefulness.

As to the naval work on shore in the electrical field, little need be said, as the practice at naval stations must be similar to that in ordinary commercial work. However, a navy yard is an ideal place for the erection of a central station for light and power. The streets must be lighted; closely grouped about the station are offices and large shops needing light in the dark afternoons and power for motor work; then in an outer approximate semi-circle are the officers' quarters, finally there are anchor chains to be welded, boiler tubes to be repaired, and numerous other similar operations which can be better accomplished by the welder than by any other known means. This in an ideal plant will call for arc lights, incandescent lights, constant potential motors, a welding generator and welders. The

complete combination will probably not be realized at any one place within several years but a good beginning has been made in the arc light plant recently installed for outside and shop lighting at the Washington Navy Yard, and the progressive plan adopted by the department leads us to hope that the shore stations will rapidly receive the benefits already enjoyed on shipboard. Owing to the usually close grouping of the buildings and to the demands for motors, it is probable that in only exceptional cases will the alternating current be used extensively. Good use is already being made of small motors for drilling purposes at the New York Navy Yard, where several are in constant operation, having driven out the portable steam engine, countershafting and belting.

The applications of electricity in the navy have always been on the increase, and any one who has served one cruise with oil lamps and one with electric lights and motors, will understand the favor in which the increasing use of electricity is held by naval men.

DISCUSSION.

DR. OTTO A. MOSES:—There is a very interesting point touched, about which I would like to inquire; whether Mr. Wilkes has himself made observations as to the deviation of the compass on board ship.

MR. WILKES:—I would say that I have not made any observations on shipboard; but the observations have been made by navigators and turned into the office of the Naval Inspector. I have seen the reports and I have made the tests on shore myself. The effect does vary between $\frac{1}{3}$ of the horizontal component of the earth and as high as 5, 6 and 7 times this component at a distance of 12 feet.

DR. MOSES:—This subject came up before a meeting of the National Electric Light Association when a Lieutenant of the Navy declared, to my astonishment, and I think to that of the other members of the Association, that there was no action on the compass at all. Have you tried experiments with the alternating current to see if that would affect the compass?

MR. WILKES:—I have never tried the alternating current because none of our ships have alternating current dynamos on board. As to the exact amount of deviation on board ship caused by the dynamo, I will state one instance in the case of the Chicago where the variation is two per cent. and it was the variation on the Yorktown, the amount of which I have forgotten, which was the cause of my investigations of dynamos before they are placed on board ship.

MR. TOWNSEND WOLCOTT:—I would like to ask Mr. Wilkes if he has ever experimented with the class of dynamos like the Continental and the Eickemeyer, called "iron-clad dynamos"—and whether there is really much difference in their effect.

MR. WILKES:—I would answer that I have. Those are the small deviations that I referred to.

MR. R. N. BAYLES:—In setting an engine aboard ship is particular care taken to set it so that the plane of the fly wheel is either fore and aft or thwart-ships? This point came out in connection with a proposed system of lighting our light-ships with an incandescent plant. Those ships roll and pitch a good deal, and one objection raised to this plan was that in case of high running machinery on board a ship, pitching around as they do, we would have the tendency of the wheels to maintain their plane of rotation—the gyroscopic effect, and that the effect would be to maintain the strain on the bearings and cause them to heat.

MR. WILKES:—I would answer that the main trouble with heating on board our men-of-war has been from having the axes of dynamo and engine faced to thwart-ships, in which case the oil is likely to fly from the bearings and it is so bad that where the available space will allow we get the shaft fore and aft. But our space is usually so cramped that we are apt to make the most of it.

MR. BAYLES:—The remark was made that this effect of the dynamo on the compass could of course be corrected. I would like to ask if there is any particular method of correcting this effect on the compass, assuming that the load is variable when it is running.

MR. WILKES:—I would answer that the effect on the compasses is not due to the lamp load as far as observation goes. The dynamos being compounded of course always exert the same effect. The mains are run so closely together that their effect is nil. I believe that in the English service where they use the ship as a return, they have considerable trouble from this cause.

MR. BAYLES:—But can it be corrected and is there a practical method of correcting it?

MR. WILKES:—I believe it has been suggested to use a larger electro-magnet to correct it. But it has never been tried in this country, and I believe that the easiest plan of correcting it is to get a dynamo which doesn't have a large external field.

MR. E. T. BIRDSALL:—I would like to ask if that 12 feet Mr. Wilkes speaks of, was clear space or were there any iron bulk heads intervening?

MR. WILKES:—The measurements were either made in engine rooms or machine shops. In the cases where the deviation is least the iron was not uniformly placed at all. It was just as you find it in any machine shop where you go to see a dynamo built, for testing it.

MR. BIRDSALL:—On almost all that I have seen of the cruisers

there was at least an iron partition, I think, between the dynamo room and any of the compasses. We know that iron of that sort has some shielding action.

MR. WILKES :—The deviations have been found on shipboard and I have often thought of the shielding action of those bulk-heads, but I believe it is anything but shielding, because they are not complete magnetic circuits and they only bring the lines of force close to the position which the compass occupies.

MR. ROBERT S. DOBBIE :—I would like to ask the lecturer if he attributes the effect only to the leakage of magnetism from the fields of the dynamo, or does he think it is the effect from the main going to the lamps. I have had a little experience with that in an alternating machine—one of the early types of Siemens machines on board a merchant vessel, and the waste of magnetism is much greater than in modern machines, and a compass adjuster from Southampton, I forget his name, a well-known man, came on board and made the most elaborate tests. The ship was wired returning through the hull. That is, the current was grounded after passing through the lamp and no perceptible difference was found on that ship, not the slightest.

MR. WILKES :—The experiment has been roughly tried by changing the position of the compass in reference to the mains and keeping approximately the same distance from the dynamo. It leads to the conclusion that the effect does come, to all observable amounts, from the dynamo itself. Did I understand you to say that you had had other experience?

MR DOBBIE :—Well, the machine was of the alternating description, so I suppose the lights made very little difference, but the magnetism escaping from the field magnets of the dynamo was, I should say, very much greater than with the modern machines. The theory of the dynamo was not so well understood in those days. There were two dynamos, an alternating dynamo with a field of eight magnets, and a small exciter.

After the election of officers the meeting adjourned, to reassemble at Boston, May 21st.

Standing Committees appointed by direction of Council:

Editing and Library Committee.

GEORGE A. HAMILTON,	} Editing.	JO. STANFORD BROWN,	} Library
FRANKLIN L. POPE,		GEORGES D'INFREVILLE,	
FRANCIS B. CROCKER.		GEORGE H. STOCKBRIDGE.	

Committee on Membership, etc.

RALPH W. POPE, Chairman.
 THOMAS D. LOCKWOOD, Local Secretary, Boston, Mass.,
 DR. LOUIS DUNCAN, " " Baltimore, Md.,
 CARL HERING, " " Philadelphia, Pa.,
 PROF. EDWARD L. NICHOLS, " " Ithaca, N. Y.,
 PROF. W. A. ANTHONY, " " Manchester, Ct.,
 JOSEPH WETZLER, New York,
 GEO. B. PRESCOTT, Jr., New York.

Committee on Finance, Building and Permanent Quarters.

GEORGE M. PHELPS, Chairman.
 GEORGE A. HAMILTON, DR. SCHUYLER S. WHEELER, THOMAS A. EDISON
 FRANKLIN L. POPE, FRANCIS R. UPTON, T. COMMERFORD MARTIN,
 DR. F. BENEDICT HERZOG.

Committee on Papers and Meetings.

T. C. MARTIN, New York, GEORGE M. PHELPS, New York, JOHN W. HOWELL, Har-
 rison, N. J., HUBERT HOWSON, New York, DR. SCHUYLER S. WHEELER, New York.

Transactions of the Institute Already Published.

Vol. I, 1884. (Out of Print.)

HISTORICAL PREFACE. NOTES ON PHENOMENA IN INCANDESCENT LAMPS.—(Illustrated.)
 Prof. Edwin J. Houston of Philadelphia.—UNDERGROUND WIRES.—(Illustrated.) W. M. Callender
 of New York.—SYNCHRONISM.—(Illustrated.) Prof. Edwin J. Houston of Philadelphia.—THE DE-
 LANY SYNCHRONOUS MULTIPLEX SYSTEM OF TELEGRAPHY.—(Illustrated.) Prof. Edwin J. Houston
 of Philadelphia.—THE SCIENTIFIC CITY STREET.—(Illustrated.) Col. Rowland R. Hazard of New
 York.—AN EXPERIMENTAL METHOD OF STUDYING THE DYNAMO MACHINE. By Prof. C. F. Brack-
 set, of Princeton, N. J.—EARTH WIRES; OR, THE EARTH AS AN ELECTRIC CIRCUIT COMPLETER.
 Thomas D. Lockwood, Boston, Mass.—TELEGRAPHING WITHOUT WIRES.—AN EXPERIMENT.
 (Illustrated.) S. J. M. Bean.—CHEMISTRY OF THE CARBON FILAMENT. Edward P. Thompson, of
 New York.—REPORTING VATS IN "SERIES." H. B. Slater, now of Leadville, Col.—THE PATENT
 OFFICE; ITS RELATION TO INVENTORS AND ITS NEEDS. C. J. Kintner, now of New York.

Vol. II, 1885.

THE PROTECTION OF ELECTRICAL INVENTIONS. F. JERLUS, of Washington, D. C.—COST OF
 MINE LIGHTING. Frank F. Mills, now of Ishpeming, Mich.—THE ELECTRIC ARC LAMP FRICTIONAL
 CLUTCH.—(Illustrated.) By Edward P. Thompson of New York.—DESCRIPTION OF A LARGE SEC-
 ONDARY BATTERY PLANT FOR GENERAL COMMERCIAL DISTRIBUTION. E. P. Roberts, of Cleveland,
 O.—DELANEY'S SYSTEM OF FAC-SIMILE TELEGRAPHY.—(Illustrated.) Prof. Edwin J. Houston of
 Philadelphia.

Vol. III, 1886. (Out of Print.)

UNDERGROUND ELECTRICAL SYSTEMS. By Sidney F. Shelbourne.—THE GREAT TANGENT
 GALVANOMETER OF THE CORNELL UNIVERSITY. Prof. W. A. Anthony, now of Manchester, Conn.—
 SOME RECENT ADVANCES IN TELEPHONY.—(Illustrated.) Thomas D. Lockwood, of Boston, Mass.—
 THE PATENT OFFICE AND PATENT OFFICE PRACTICE. A. C. Fowler, of New York.—STATIC DIFFICUL-
 TIES IN TELEGRAPH WIRES. F. W. Jones of New York. Containing a Synopsis, with reference
 to 113 American and Foreign Patents for inventions intended to overcome these difficulties.—SEC-
 ONDARY BATTERIES FOR LIGHT AND POWER. A. H. Bauer.—THE WIRE GAUGE. Report of Commis-
 sion.—NOTES ON DYNAMIC INDUCTION. Sidney F. Shelbourne.

Vol. IV, 1887. (Out of Print.)

ELECTRIC STREET CARS. T. C. Martin, of New York.—THE PRACTICAL REQUIREMENTS OF
 SMALL MOTORS. S. S. Wheeler, of New York.—DISTRIBUTION OF ELECTRICITY BY SECONDARY
 GENERATORS. Discussion by F. L. Pope, Dr. Otto A. Moses, Captain O. E. Michaelis, Prof. Elihu
 Thomson and others.—STORAGE BATTERIES IN PRACTICE. E. P. Roberts, of Cleveland, O.—
 DIFFERING TEMPERATURE COEFFICIENTS OF THE DIFFERENT COILS OF A FINE RHENOSTAT. Prof.
 W. A. Anthony, now of Manchester, Conn.—ON THE BEST RATIO OF THE SECTION OF THE GRASSES
 APPERTAINING TO THE SECTION OF THE FIELD MACHINERY.—(Illustrated.) Dugald C. Jackson, now of
 Lincoln, Neb.—NOVEL PHENOMENA OF ALTERNATING CURRENTS.—(Illustrated.) Prof. Elihu
 Thomson, of Lynn, Mass.—A FEW COMPARATIVE STATISTICS OF ELECTRIC RAILWAYS. T. C.
 Martin, of New York. (With tabular statement.)—CENTRAL STATION CONSTRUCTION. J. A.
 Powers, of Troy, New York.—ON THE CHANGE FROM NEGATIVE TO POSITIVE OF THE TEMPERA-

THERMOCOEFFICIENTS OF SOME CARBON FILAMENTS. (Illustrated.) Prof. W. A. Anthony, of Manchester, Conn.—LEAD ENCASED CONDUCTORS. (Illustrated.) David Brooks, of Philadelphia.—THE ELECTRIC LIGHTING OF PASSENGER TRAINS. (Illustrated.) Geo. W. Blodgett, of Boston.

Vol. V, 1887-8.

ON ELECTRIC STREET CARS, WITH SPECIAL REFERENCE TO METHODS OF GEARING. Anthony Reckenzaun, of London. No. 1, October, 1887.—A COULOMB METER, OR INSTRUMENT FOR MEASURING THE CONSUMPTION OF ELECTRICITY. (Illustrated.) Prof. George Forbes, F.R.S., of London. No. 2, November, 1887.—RECENT IMPROVEMENTS IN APPARATUS FOR OCEAN CABLES. (Illustrated.) Charles Cuttriss. Supplementary Note on the Siphon Recorder, and Ocean Telephony, by Thos. D. Lockwood. No. 3, December, 1887.—PHENOMENA OF RETARDATION IN THE INDUCTION COIL. (Illustrated.) William Stanley, Jr. No. 4, January, 1888.—REVISION OF THE PATENT LAW. Arthur Steuart, Esq. No. 5, February, 1888.—ELECTRIC ENERGY FROM CARBON WITHOUT HEAT. Willard E. Case, Auburn, N. Y. No. 6, March, 1888.—ALTERNATING CURRENT ELECTRIC MOTORS. Dr. Louis Duncan, Baltimore, Md. No. 7, April, 1888.—MAXIMUM EFFICIENCY OF INCANDESCENT LAMPS. (Illustrated.) John W. Howell. No. 8, May, 1888.—PROTECTION OF THE HUMAN BODY FROM DANGEROUS CURRENTS. Patrick B. Delany.—THE POSSIBILITIES AND LIMITATIONS OF CHEMICAL GENERATORS OF ELECTRICITY. Francis B. Crocker. No. 9, June, 1888.—ON COMPENSATED RESISTANCE STANDARDS. (Illustrated.) Edward L. Nichols. A NEW SYSTEM OF ALTERNATE CURRENT MOTORS AND TRANSFORMERS. (Illustrated.) Nikola Tesla. UNDERGROUND ELECTRICAL CONDUCTORS IN EUROPE AND AMERICA. Prof. G. W. Plympton. THE PATENT COURT AND UNIFORMITY IN PATENT OFFICE PRACTICE. George H. Stockbridge. A SWINGING ARM GALVANOMETER. (Illustrated.) George S. Moler. No. 10, July, 1888. THE SOLUTION OF THE MUNICIPAL RAPID TRANSIT PROBLEM. (Illustrated.) Frank J. Sprague. No. 11, August, 1888. SOME OBJECTIONS TO THE OVERHEAD CONDUCTOR FOR ELECTRIC RAILWAYS, M. B. Leonard. NOTE ON GEARING FOR ELECTRIC RAILWAY MOTORS, Almon Robinson. No. 12, September, 1888.

Vol. VI, 1889.

[Including October, November and December, 1888.]

THE GEYER-BRISTOL METER FOR DIRECT AND ALTERNATING CURRENTS. [Illustrated.] Prof. William E. Geyer. THE ASDANK MAGNETIC CALL AND THE ASDANK INTEGRAPH. [Illustrated.] E. Abank-Abankowicz. No. 1, January, 1889. SIX YEARS PRACTICAL EXPERIENCE WITH THE EDISON CHEMICAL METER. (Illustrated.) W. J. Jenks. No. 2, February, 1889. LIGHTNING ARRESTERS AND THE PHOTOGRAPHIC STUDY OF SELF-INDUCTION. (Illustrated.) E. G. Acheson. No. 3, March, 1889. A NEW SYSTEM OF MULTIPLEX TELEGRAPHY. (Illustrated.) Lieut. F. Jarvis Patten. LIGHTNING ARRESTERS AND THE PHOTOGRAPHIC STUDY OF SELF INDUCTION. Notes by Jo. Stanford Brown and Chas. T. Child. REPLY TO THE NOTES OF MESSRS. BROWN AND CHILD BY E. G. Acheson. No. 4, April, 1889. THE EFFICIENCY OF METHODS OF ARTIFICIAL ILLUMINATION. Illustrated. Edward L. Nichols. No. 5, May, 1889. SOME RESULTS WITH SECONDARY BATTERIES IN TRAIN LIGHTING. (Illustrated.) Alexander S. Brown. THE INHERENT DEFECTS OF LEAD STORAGE BATTERIES. (Illustrated.) Dr. Louis Duncan. ELECTRIC MOTOR REGULATION. (Illustrated.) Francis B. Crocker. Nos. 6 and 7, June and July 1889, (Double Number). MAGNETISM IN ITS RELATION TO INDUCED ELECTROMOTIVE FORCE AND CURRENT. (Illustrated.) Prof. Elihu Thomson of Lynn, Mass. ON THE RELATION BETWEEN THE INITIAL AND THE AVERAGE EFFICIENCY OF INCANDESCENT LAMPS. (Illustrated.) W. H. Peirce of New York. THE EFFICIENCY OF THE ARC LAMP. (Illustrated.) H. Nakano, of Japan, with an introductory note by Prof. E. L. Nichols. THE SPIRAL COIL VOLTMETER. (Illustrated.) Harris J. Ryan, of Ithaca, N. Y. THE PERSONAL ERROR IN PHOTOMETRY. (Illustrated.) Prof. Edward L. Nichols, of Ithaca, N. Y. ON MODERN VIEWS WITH RESPECT TO ELECTRIC CURRENTS. (Illustrated.) Prof. Henry A. Rowland, of Baltimore, Md. CLASSIFIED LIST OF MEMBERS. Nos. 8 and 9, August and September, 1889, (Double Number). No. 10, October, 1889. SOME RECENT ELECTRICAL WORK ON THE ELECTRIFIED RAILROADS. (Illustrated.) Leo Daft, of Plainfield, N. J. ALTERNATING CURRENT MOTORS: THE EVOLUTION OF A NEW TYPE. (Illustrated.) Lieut. F. Jarvis Patten, of New York. No. 11, November, 1889. ELECTRICAL NOTES OF A TRANS-ATLANTIC TRIP. Thomas D. Lockwood, of Boston, Mass. SOME METHODS OF REGULATING ACCUMULATORS IN ELECTRIC LIGHTING. (Illustrated.) George B. Prescott, Jr., of New York. No. 12, December, 1889. FORM AND EFFICIENCY OF INCANDESCENT FILAMENTS. Charles J. Reed of New York. TELEGRAPH LINE ADJUSTMENT:—NOTE ON A NEW GRAVITY CELL. P. B. Delany of New York.

Vol. VII, 1890.

TRANSFORMERS. (Illustrated.) Harris J. Ryan. No. 1, January, 1890. A REVIEW OF THE MODERN THEORIES OF ELECTRICITY. (Illustrated.) Prof. W. A. Anthony. No. 2, February, 1890. THE PRACTICAL WORKING OF THE ELECTRICAL SURVEYS OF NEW YORK CITY. (Illustrated.) William Mayer, Jr. No. 3, March, 1890. SOME TESTS ON THE EFFICIENCY OF ALTERNATING CURRENT APPARATUS. (Illustrated.) Dr. Louis Duncan and W. F. C. Harrison. No. 4, April, 1890. PHENOMENA OF ALTERNATING CURRENT INDUCTION. (Illustrated.) Prof. Elihu Thomson. ELECTRICITY IN THE NAVY. Gilbert Wilkes, No. 5, May, 1890.

SPECIAL NOTICE

TO MEMBERS AND SUBSCRIBERS.

Those who desire to preserve complete files of the TRANSACTIONS should care for each number as it is received, and inform the Secretary if any are missing. The annual volume will be made up from these monthly parts, without further revision.

Temporary binders for filing the numbers as issued will be furnished at 75 cents each.

Members having copies of Volumes I, III or IV, which they are willing to dispose of, may find customers by addressing

RALPH W. POPE, *Secretary.*